

REPORT DOCUMENTATION PAGE

AFRL-SR-AR-TR-03-

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering the data, reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Project (0304-0188), Washington, DC 20503.

0081

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED

01 Jun 96 to 30 Sep 99 FINAL

4. TITLE AND SUBTITLE

Investigations of Crystalline Organic Nanostructures Grown by Ultrahigh Vacuum and Vapor Phase Techniques

5. FUNDING NUMBERS

61102F

2305/EX

6. AUTHOR(S)

Dr Forrest

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

PRINCETON UNIVERSITY
OFFICE OF RESEARCH AND PROJECT ADMIN
509 NEW SOUTH BLDG
PO BOX 36

PRINCETON NJ 085454-0036

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

AFOSR/NE
4015 WILSON BLVD
SUITE 713
ARLINGTON VA 22203

8. PERFORMING ORGANIZATION
REPORT NUMBER10. SPONSORING/MONITORING
AGENCY REPORT NUMBER

F49620-96-1-0277

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

We demonstrated the highly oriented growth of an organic salt using the new process of low pressure organic vapor phase deposition (LP-OVPD). This follows on our earlier work in the demonstration of atmospheric pressure OVPD. In the kinetic regime of LP-OVPD, however, there is improved surface morphology and crystalline alignment, to the point that we can now routinely achieve the alignment of DAST thin films across entire wafer surfaces. The material is excellent for optical modulators. We are currently investigating a modulator design which employs titanium dioxide waveguides coated with oriented DAST films. The wave propagating in the waveguide is evanescently coupled into the organic film which can be used to shift the phase of the wave by application (through electrodes) of an electric field. One milestone for the coming year is to demonstrate low voltage DAST-based phase modulators grown using LP-OVPD. This work is being published as an invited paper in Advanced Materials.

14. SUBJECT TERMS

20030416 223

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION
OF REPORT

UNCLASSIFIED

18. SECURITY CLASSIFICATION
OF THIS PAGE

UNCLASSIFIED

19. SECURITY CLASSIFICATION
OF ABSTRACT

UNCLASSIFIED

20. LIMITATION OF ABSTRACT

UL

Standard Form 298 (Rev. 2-89) (EG)
Prescribed by ANSI Std. Z39.18
Designed using Perform Pro, WHS/DIOR, Oct 94

COVER SHEET

Program Title: Investigations of Crystalline Organic Nanostructures Grown
by Ultra-High Vacuum and Vapor Phase Techniques

Grant No.: F49620-96-1-0277

PI Name: Stephen Forrest

Institution: Center for Photonics and Optoelectronic Materials
Department of Electrical Engineering and
Princeton Materials Institute
Princeton University
Princeton, NJ 08544
(609) 258-4532

DISTRIBUTION STATEMENT A

Approved for Public Release
Distribution Unlimited

1. Current Progress and Accomplishments in FY98

This past year has been spent primarily in investigating excited states in organic thin films for use in laser and organic light emitting devices (OLEDs). We were the first group to unequivocally observe lasing action in organic semiconductor films using optical pumping techniques. This work, which included development of a fundamental understanding of the quantum nature of lasing action in doped systems was published in *Nature*, *Science*, *Journal of Applied Physics* and *Applied Physics Letters*. Two of the most interesting findings of this work were the observed temperature insensitivity of the organic laser characteristics (due to the similarity between dye doped organics and quantum dot lasers), and the very narrow spectral linewidths characteristic of organic emitters. Since those early results, we have concentrated on quantifying the nature of organic films under very high pulsed electrical injection ($\sim 300 \text{ A/cm}^2$) which is needed for pumping electrically excited organic laser diodes. We find that polaron absorption is a significant problem in organic thin films which may ultimately raise the threshold current of organic laser diodes to unacceptably high levels. Currently, we are concentrating on fabricating organic laser diodes employing transparent contacts for both electron and hole injection. Early results on Fabry-Perot laser structures under intense electrical pumping show a narrow spectral output but no spectral narrowing with pump intensity. We are currently investigating the source of this interesting effect.

In a parallel effort, we have demonstrated that organic *phosphors* doped into conducting hosts can lead to very high efficiency OLEDs. This is in contrast to previous work where only fluorescent emission was employed using dyes doped into conductive organic thin films. In these studies, we discovered that the red emitting organic phosphor, PtOEP, could emit with nearly 6% external efficiency when doped into the appropriate host such as carbazol biphenyl. The decay time of the emission was 30 μs , which is adequate for all display applications. Furthermore, we have used organic electrophosphorescence to investigate such fundamental processes as the singlet-to-triplet ratio in aluminum tris(8-hydroxyquinoline). This study should provide fundamental insights into spin statistics in organic molecular systems. The work has been published in *Nature* and we have submitted papers to *Physical Review Letters* and *Applied Physics Letters* on this exciting new area of research.

Finally, this year we demonstrated the highly oriented growth of an organic salt using the new process of low pressure organic vapor phase deposition (LP-OVPD). This follows on our earlier work in the demonstration of atmospheric pressure OVPD. In the kinetic regime of LP-OVPD, however, there is improved surface morphology and crystalline alignment, to the point that we can now routinely achieve the alignment of DAST thin films across entire wafer surfaces. The material is excellent for optical modulators. We are currently investigating a modulator design which employs titanium dioxide waveguides coated with oriented DAST films. The wave propagating in the waveguide is evanescently coupled into the organic film which can be used to shift the phase of the wave by application (through electrodes) of an electric field. One milestone for the coming year is to demonstrate low voltage DAST-based phase modulators grown using LP-OVPD. This work is being published as an invited paper in *Advanced Materials*.

2. Program Statistics

- (1) PI: Stephen Forrest
- (2) Number of post docs supported: 2 (P. E. Burrows and V. Bulovic)
- (3) Number of grad students supported: 2 (M. Baldo and G. Parthasarathy)
- (4) Other researchers supported: 1 Part time (M. Valenti)
- (5) Number of publications in the last 12 months in refereed journals: 25
- (6) Number of publications acknowledging AFOSR support: 12
- (7) Awards and Honors Received by the PI:
 - Horace Rackham Fellowship (Physics), University of Michigan
 - Knoller Scholarship for Physics and Chemistry, University of Michigan
 - TRW Faculty Assistance Award in Electrophysics, University of Southern California
 - Powell Foundation New Investigator Award, University of Southern California
 - Fellow, IEEE
 - 1996-1997: IEEE Distinguished Lecturer: "Organic Materials for Photonics"
 - 1997: IEEE LEOS Ann. Mtg. Best Student Paper Award. Student: V. Bulovic, Adv.: S. Forrest
 - 1998: Intellectual Property Owners Distinguished Inventor of the Year: "Multicolor Organic Light Emitting Devices"
 - 1998: Thomas Alva Edison Award for innovation in emerging technology: "Multicolor Organic Light Emitting Devices"

3. Transistions

- a. S. Forrest, Princeton University: b. Growth of DAST by OVPD: c. V. Ban, PD-LD, Inc., 609 924 7979: d. Optical Modulators
- b. S. Forrest, Princeton University: b. Organic LED and laser technology: c. J. Brown, Universal Display Corp., 610 617 4010: d. Display and optical sensing applications